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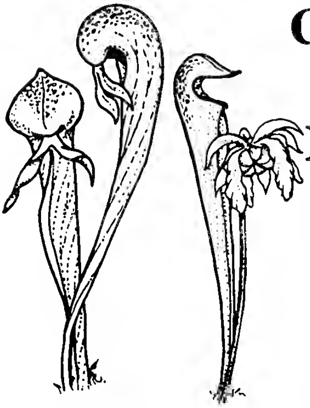

CARNIVOROUS PLANT NEWSLETTER

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Front Cover: Flowering *Aldrovanda* in cultivation. Photo by T. Nishida.
Rear Cover: This dystrophic *Aldrovanda* lake is bordered by undisturbed littoral vegetation. Europe, 1993. Photo by C. Breckpot.

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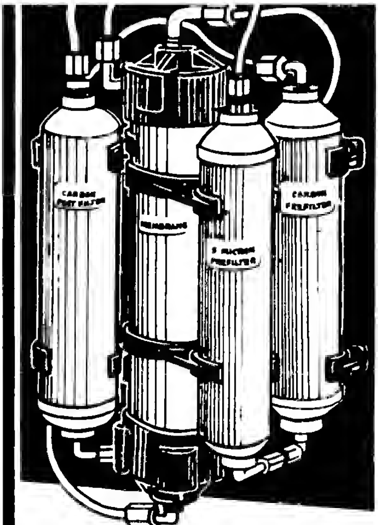
EDITORIAL

BARRY MEYERS-RICE

A long time has passed time since an issue of Carnivorous Plant Newsletter had a theme; this one is dedicated to *Aldrovanda vesiculosa*—an aquatic relative to the Venus Fly Trap. *Aldrovanda* is almost always absent from plant collections, so you may not know much about it. Now you can read about what you have been missing—this issue contains articles reviewing the plant's distribution, habitat, and evolution, all written by an international cast of authors. Articles describing cultivation methods, both in trays and in tissue culture, have been included to guide you in your own horticultural efforts. (Peter D'Amato's regular column, The Savage Garden, is taking a break but will return next issue.) Now read on, and marvel at the serene beauty and finicky tastes of the extraordinary Waterwheel Plant...



Aldrovanda vesiculosa: Description, Distribution, Ecology and Cultivation

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Description

This plant was first cited as *Lenticula palustris Indica* in 1696 by Plukenet. In 1747 Monti described and named it *Aldrovandia* in honor of the Italian naturalist Ulisse Aldrovandi (1522-1605). Finally in 1753 Linnaeus took over Monti's description and in his Species Plantarum used the name *Aldrovanda vesiculosa*, which has been noted as being an orthographic error (Duval-Jouve, 1861), although the original spelling is to be retained. Since the last part of the 19th century *Aldrovanda* has been studied extensively. It is commonly known as the Waterwheel Plant.

The genus *Aldrovanda* is monotypic nowadays, but it probably contained more species in the past (Huber, 1961; Degreef, 1997). The Waterwheel Plant belongs to the family Droseraceae. As an aquatic, it is clearly separated from the rest of the family.

The rootless plant floats just below the water surface (Figure 1). The measurements of different parts of the plant body are rather variable. The length of adult plants ranges between (1.5)6—11(20) cm with a shoot diameter 1 to 2 cm (Aston, 1983). The serrulate stems are 0.6—0.7 mm wide and basically simple (Caspary, 1859). In plants growing under favourable conditions, the main shoots usually branch after every 3—4 cm (5—7 whorls) giving rise to short lateral branches in the axils of whorls. In time these branches may form offshoots. In temperate regions where *Aldrovanda* rarely flowers (bearing only abortive or no seeds), this is the only way of reproduction. In average 12 to 19 whorls are arranged along the stem (Kaminski, 1987a) like spokes in a wheel and each whorl consists of (5)7—8(9) leaves 7—11 mm long (Caspary, 1859). The distance between grown-up whorls ranges between 0.5 to 0.7 cm (Kaminski, 1987a). When in growth new whorls are formed at the plant's apex, while the oldest whorls and internodes at the rear die (Ashida, 1934). The rate of stem elongation of plants in Japan has been found to be 0.4—0.9 cm/day (Komiya, 1966). This fast growth is unrivaled among terrestrial carnivores, none of which produces a new rosette or even a new leaf every day!

The leaf consists of a dorsally flattened petiole, 5—6(9) mm long (Caspary, 1859), connate at the base, broadened upwards and ending in a trap and (1)4—6 pointed bristles, each 6—8 mm long (Diels, 1906), arranged laterally and dorsally to the trap. The bristles protect the traps from being unintentionally closed by floating debris. The petiole is important for the plant's photosynthesis and contains air chambers which contribute to helping the plant float.

The Waterwheel Plant has the same trap mechanism as *Dionaea muscipula*, but the traps are smaller and function under water (Iijima, 1981). Darwin named it "the miniature aquatic *Dionaea*" (Darwin, 1896). The trap closes with amazing rate within 0.01—0.02 seconds (Ashida, 1934, 1935). This is one of the most rapid movements found in plants. The details of how the trap closes are still rather obscure.

The traps have a leaf-blade consisting of two semicircular lobes, convex outwards, each 4—5 mm wide and 5—7 mm long and connected along the midrib. The trap stalk is twisted 90^{0} to the left. This way, one lobe is turned to the bristles and is called the bristle-side lobe. The other lobe looks away from the bristles and is called the free-side lobe (Ashida, 1934). In addition to this torsion, the trap is bent backwards through an angle of $30—40^{0}$. These torsions are of an evolutionary importance because the chance of catching prey is enhanced when the mouths of the traps face outwards from the stem (Lloyd, 1942). When the trap closes, the free-side lobe bends to a greater extent than the opposite lobe. This explains the asymmetrical shape of the closed trap (Ashida, 1934).

Each lobe consists of two regions, a thin two layered marginal and thicker three layered central one. Note how delicate the lobes are! The border line between the two regions is called the enclosure boundary (Ashida, 1934). The margin of each lobe is bent inwards and carries 60—80 small teeth (Fenner, 1904). Trigger hairs are found in the central zone. They are 0.5—1.5 mm long, 0.05 mm wide (Lloyd, 1942), 30—40 in number, of which 18—20 are near the midrib and 7—9 are near the enclosure boundary (Haberlandt, 1906).

In temperate regions the plants survive winter by means of elliptic turions (with acute poles) about 4—6 mm long. Under ideal conditions these sink to the bottom of the lake and start floating again as they start to grow next spring. In tropical regions the plant grows throughout the year without forming turions. The plants flower and set seed towards the end of summer only in warmer climates where water temperature are higher than 25^{0}C (77^{0}F). The small solitary 8 mm flower (Lloyd, 1942) arises above the water surface, carried by a short 5—15 mm (Aston, 1983) robust peduncle emerging from a whorl axil (see front cover). The capsule becomes pendulous after flowering.

The flower has a strict pentamerous structure with five sepals, white or tinged pink petals, stamina and styles. The ovary is unilocular, superior, subglobulose, with 4 or (usually) 5 placentas bearing 8—13 ovula. The placentation is parietal. The capsule is globulose, membranous, 4 mm long, 3 mm wide, and up to 1.5 times the length of the sepals (Aston, 1983). Seeds number mostly 6—8 per capsule or rarely fewer (Diels 1906), are broadly ellipsoidal with a short thick basal foot, are operculate, black, shiny and measure 1.5×1 mm (Diels, 1906). The pollen grains are 45—63 µm large, and are united in tetrads. Each grain has three pores with an operculum (Takahashi & Sohma, 1982).

Distribution (Focusing on Europe)

Aldrovanda vesiculosa is distributed widely. It grows in Africa, Asia, Australia and Europe but is absent from North and South America (Caspary, 1859; Berta, 1961; Jäger, 1964) and Antarctica. The species has its most northern distribution in Europe. With its sophisticated mobile traps, one might think that *Aldrovanda* would be at the top of the evolutionary ladder and therefore of recent origin. But this is not so. The morphology of the flower and the age of fossil seeds and pollen (Huber, 1961; Degreef, 1997) are indications of the archaic character of the plant.

The oldest traces of the Waterwheel Plant in Europe are seeds and pollen from the Upper Cretaceous (85—75 MYA) and Eocene (55—38 MYA), respectively (Knobloch & Mai, 1991; Huber, 1961). The warm Tertiary climate was favourable for a wide distribution of the plant. Later, during the glaciations of the Quaternary; *Aldrovanda* was regularly driven back to southern Europe (Berta, 1961). More about the fossil record of *Aldrovanda* in another article in this volume (Degreef, 1997). The question of the origin of modern Waterwheel Plants in Europe is still unsolved. Two theories have been formulated. According to some authors the plant is a relict of the Tertiary flora (e.g. Berta, 1961). They assume that the plant never

disappeared completely from the continent. This theory is supported by numerous fossil records, the fragmented distribution of today and the fact that *Aldrovanda* forms turions which might be an evolutive adaptation for plants in temperate regions. Jäger (1964) states that the modern plants were introduced by migratory birds coming from the tropics (see below). This theory is partly supported by the plant's absence in North and South America and the fact that there is no longer a species diversification. We do not know which theory is correct. A study of growth behaviour of African plants grown in temperate Europe (i.e. do they form turions?) and investigation of the genetical differences between European and African plants would help to solve the mystery (Studnicka, 1984). Unfortunately, there are no records of recent observations in Africa.

Today, *Aldrovanda* is dispersed irregularly and sparsely over a large part of central and eastern Europe (Berta, 1961; Jäger, 1964).

Looking at a distribution map indicating all 19th and 20th century sites (Berta, 1961), we see that the northernmost distribution in western Europe was situated in southern France whereas in eastern Europe it was much more to the north, in the neighbourhood of St. Petersburg in Russia (60.5 parallel). Apparently the winter temperatures are not so determinative for its distribution. This a bit strange for a plant which is known as loving a warm climate. And why is the species absent from northwest Europe with its milder winters? The point is that it is not the winter but the summer which determines where *Aldrovanda* grows. If the water temperature during the growing season is sufficiently high, then the plants survive. This explains why the species does not grow in northwest Europe with its mild summers, but on the other hand does grow in northeast Europe with its warmer continental summers.

Discoveries of the Waterwheel Plant were published in the literature from the 18th and especially from the 19th century on. That time the plant was found in many countries: France, Switzerland, Germany, Poland, Czechoslovakia, Austria, Hungary, Romania, Belarus, Baltic, Ukraine, Russia, Italy, Yugoslavia, and Bulgaria (Caspary 1859). It can be assumed that the influence of human activities on the distribution of *Aldrovanda* was not substantial before 1940.

Today *Aldrovanda* occurs in Hungary, Italy(?), Poland, Romania, Switzerland (where it is introduced) and the countries now called Yugoslavia, Ukraine and Russia. The serious decline of the species during this century is most likely caused by the destruction and disturbance of its sites by man (water drainage, pollution by agriculture and industry, and disturbance by recreation). As the plant's ecological requirements are very strict, it is very sensitive and is one of the first plants to disappear. This extreme sensitivity is to be expected for a plant at the edge of its distribution.

In western Europe the decline is spectacular and the plant is almost extinct. But it must be stressed that the number of sites there was smaller than those in eastern Europe. The plant still grows in eastern Europe. Here too the disappearance is alarming, but less striking because of the higher number of sites. The expected future agricultural, touristic and industrial development in that part of the continent will not bring much good for *Aldrovanda*.

How does *Aldrovanda* spread to other places? Most likely this happens via turions or whole plants. In (sub-)tropical areas, seeds might get dispersed too. Three likely dispersal agents are described below.

a)Birds

According to Jäger (1964) birds play an important role in the distribution of the plant. A turion, seed, or less likely a whole plant may get stuck to a bird's legs or feathers and thus be carried to another place. Theoretically, a seed could, once eaten, land somewhere else via the excrements of the bird. This is speculative as we do not know whether these minute seeds are eaten and whether the viability is still

intact after passing through the intestines of the bird. The occurence in mountainous regions is most likely a result of introduction by birds. The similarity between the worldwide distribution of *Aldrovanda* and the routes of some migratory birds is remarkable (Jäger, 1964; Studnicka, 1984). So birds might play a role for long distance transport between continents as well as for short distance spread.

b)Flowing Water

In regions with interconnected habitats, the plant can be brought to another place by the natural flow in the canals and streams.

c)Flooding

Habitual floodings in floodplain areas might transport *Aldrovanda* to isolated pools.

It is likely that the plant will disappear from Europe in the future. To prevent it from vanishing, the sites must be protected. Protection alone will not preserve *Aldrovanda* from extinction, because most disturbance is caused by factors coming from outside the habitats. Despite a number of possible threats, the exact reasons for vanishing are often unknown.

(Re-)Introduction might help to maintain the species. To be successful the knowledge of *Aldrovanda*'s ecological requirements must be completed first. Suitable alternative sites are becoming very rare these days.

To prevent further genetic impoverishment, there is an urgent need for a gene stock of plants of different origins. Suitable methods for stockage are tissue culture and cryopreservation. Propagation methods (in vitro and in vivo) need to be optimized so that natural populations can be left undisturbed and only propagated specimens should be used for all kinds of experiments.

Being ousted by competing species, *Aldrovanda* has to move regularly to survive. The shorter the travelling distances, the greater the chance of survival. *Aldrovanda* is able to survive for a long time only in areas with enough suitable habitats close to each other.

Ecology

Aldrovanda has a weak competition ability with surrounding plants. Space, nutrients and light are in limited supply. The only way to withstand elimination is by vigorous growth and propagation. These are promoted by a number of factors, discussed below.

As a free floating aquatic, *Aldrovanda* grows in pools, lakes and river deltas in standing water (Berta, 1961). Typically it is found near the shore, loosely surrounded by other plants (Figure 2). This very productive zone is characterized by rapid succession among different plant populations. So soon *Aldrovanda*'s place will be taken by others and the species will have to migrate to new places.

The plant prefers shallow water less than 1 m deep. As the plant is very susceptible to dessication, a permanent water level is essential throughout the growing season. Most of the time the bottom of the stands is covered with a thick layer of partly decomposed plant remains. In temperate regions the water surface might freeze in winter. The shallower the water, the higher the risk the turions will be killed by the ice. So it may be advantagous for turions to overwinter at places with a considerable water depth (Kaminski 1987b).

The water in *Aldrovanda* stands is mesotrophic and thus medium-rich in nutrients. In oligotrophic waters the plant is always absent. Eutrophication of the water (by intensive agriculture) is thought to be one of the major reasons for the disappearance of the plant. The pH of natural waters ranges between 5.6 and 6.8 (Komiya, 1966; Kaminski, 1987a).

The analysis of the water in Polish sites yielded the following results: 0.3—0.6 mg/l $N\text{-}NO_3$, 1.0—1.5 mg/l $N\text{-}NH_4$, about 0.06 mg/l $P\text{-}PO_4$, 2.4—4.0 mg/l K, less than

40 mg/l Ca, 6.0—15.0 mg/l Mg, 8.0—13.0 mg/l Na, 0.5—1.0 mg/l Fe, 25 mg/l SO_4, 5.0—12.0 mg/l Cl, and 3—5 mg/l of organic carbon (Kaminski, 1987a).

The decomposition of plant material results in the production of organic humic acids. Their concentration in *Aldrovanda* stands is medium (3—5 mg/l). Waters like these are called dystrophic. Typically, high concentrations of humic acids are found in lakes with a thick layer of plant residues at the bottom. The humic acids are important for *Aldrovanda*. They are responsible for a much better plant growth during the growing season and they seem to regulate the sinking of the turions (Kaminski 1987b).

Carbon dioxide is the carbon source for photosynthesis allowing a plant to grow. *Aldrovanda* needs relatively high concentrations of CO_2 (0.5—2 mM) (Adamec, 1994). One of the main sources of carbon dioxide is the thick organic layer at the lake bottom, where it results from the decomposition of the organic material. So it is advantageous for *Aldrovanda* to float near this source in shallow water. Phytoplankton, filamentous algae and other aquatic plants can deplete the CO_2.

During the growing season *Aldrovanda* needs relatively warm water: at least 16°C (61°F), ideally 23—30°C (74—86°F) (Saito, 1972; Haldi, 1974; Mazrimas, 1978). The water warms up most rapidly at places with low water depth (typically near the shore), dark coloured bottom and full sun.

The turions sink to the bottom of the lake in autumn where they overwinter, being protected from the surface frost by the insulating ice above them. Under less favourable conditions the turions fail to sink (Schoenefeld, 1860).

Aldrovanda prefers places with high irradiance (Saito, 1972; Haldi, 1974; Hanabusa, 1974). Light is needed for photosynthesis and warms the water. Several factors influence the availibility of light to the plant. First of all, the vegetation above the water surface, which should not be too close, too dense or too high, can block light. Floating and submerged plants can intercept light too, so the Waterwheel Plant prefers loose plant communities with nearby open water (see back cover). Another factor is the transparency of the water. Suspended matter, algae and/or phytoplankton can make the water less transparent and thus reduce the amount of light for *Aldrovanda*. The Waterwheel Plant is very susceptible to overgrowing by filamentous algae (Saito, 1972; Haldi, 1974).

Quite a number of other macrophytes can be found near *Aldrovanda*, indicating its rather large phytosociological range (Figure 3). European populations belong to the floristic unions Nymphaeion, Phragmition and Magnocaricion (Caspary, 1859; Berta, 1961; Kaminski, 1987a). Plants secrete chemical substances which can influence the growth of other plants. The influence can be positive or negative. It has been confirmed experimentally that accompanying plants influence the growth of *Aldrovanda* in a positive way (Kaminski, 1987b). They seem to produce some vital chemical substances. The nature of these chemicals is still unknown. Some important stimulating neighbours are: *Typha latifolia*, *Stratiotes aloides*, *Phragmites australis*, *Carex* spp., and *Hydrocharis morsus-ranae*. *Aldrovanda* only appreciates the company of other plants as long as the vegetation remains open. In Europe, *Utricularia vulgaris* or the related *U. australis* are often found in the neighbourhood of *Aldrovanda*. Although the two genera regularly occur together, *Utricularia* is much less rare than *Aldrovanda*.

One might expect prey is useful for every carnivorous plant, but from cultivation experience it appears that a number of carnivorous plants can live perfectly without it. In the case of *Aldrovanda*, prey plays an important role (Kaminski, 1987b). Zooplankton populations are always considerable in communities with the plant. Probably zooplankton is a source of substances which *Aldrovanda* can not take up from water in sufficient amount. Standing waters are preferred as here there is little chance that the traps may be closed unncecessarily by movements in the water.

Figure 1: *Aldrovanda vesiculosa*. Photo by C. Breckpot.

A number of populations have disappeared by the draining of lakes. Some habitats still exist but for unclear reasons the plant has disappeared there too—most likely changes in the water quality are reponsible. The water chemistry can be influenced by precipitation and by runoff. Changes of water content do not necessarily influence *Aldrovanda* directly. They might speed the decomposition processes in the bottom sediment. As a result the nutrient levels in the water rise (Bloemendaal & Roelofs, 1988). This situation might be beneficial for competitor plants (macrophytes and algae) resulting in dense plant communities with reduced light availability and CO_2 depletion. For weak competitors like *Aldrovanda*, one or a combination of the results of eutrophication might become fatal in time.

It is unclear at what growth stage *Aldrovanda* is most susceptible. Probably the sprouting of the turion is the most critical point. Changes in the structure and chemistry of the bottom sediments (increased concentrations of toxic substances like sulfides and ammonia) and reduction of the transparency of the water might inhibit the germination process as suggested in studies of the decline of *Stratiotes aloides* (Bloemendaal & Roelofs, 1988).

In temperate zones, the reproduction of *Aldrovanda* only takes place vegetatively. This means that all specimens of a stand are more or less genetically identical. So all individuals are equally susceptible and react similarly to changed conditions. When conditions become less favourable, the lack of genetic diversity is a disadvantage and can lead to a rapid disappearence of the population (Weeda *et al.*, 1991). On the other hand, when the conditions are right *Aldrovanda* might form extensive populations in a short time (Ohtaki & Katagiri, 1974).

Figure 2: In this characteristic habitat *Aldrovanda* is accompanied by *Stratiotes aloides* and *Hydrocharis morsus-ranae*. Europe, 1993. Photo by C. Breckpot.

Cultivation

The cultivation of the Waterwheel Plant is often said to be (extremely) difficult. Although it is not the most ideal plant to start a carnivorous plant collection with, most problems can be overcome by good

planning, regular follow-up and sufficient knowledge of the plant's needs.

To be successful, *Aldrovanda*'s ecological requirements need to be respected strictly (Ohtaki & Katagiri, 1974). The creation of a suitable aquatic habitat is not as easy as mixing two parts peat to one part sand! Water chemistry is complicated and a lot of factors interact with each other. If you start to create the biotope after you obtained *Aldrovanda*, you are probably acting too late and are likely to lose the plant. Therefore, the habitat needs to be prepared months in advance. As soon as the water conditions have become suitable and stable, the Waterwheel Plant can be introduced safely.

Figure 3: Stand dominated by *Phragmites australis* and *Hydrocharis morsus-ranae*. The largest concentrations of *Aldrovanda* are found at places like this. It is likely that wind and water currents contribute to the concentration of plants. Europe, 1993. Photo by C. Breckpot.

The best place to grow *Aldrovanda* is outdoors in an earthenware or plastic container. I grow my plants in a round plastic lily pond 1 metre in diameter and 35 cm deep. It is important to use a relatively shallow container with a large surface area. The smaller the volume of your container, the more difficult it will be to create and maintain stable conditions. The tank can be protected from curious birds with a net. There are a few records of cultivation indoors (Ashida, 1934; Ohtaki & Katagiri, 1974), but I doubt that the plant can be grown that way for prolonged periods.

Aldrovanda prefers places with abundant light (Saito, 1972; Haldi, 1974; Hanabusa, 1974; Ohtaki & Katagiri, 1974). Light is needed for photosynthesis and warms the water, which the Waterwheel Plant definitely appreciates. It is still unclear whether full or half-sun is best (Kaminski, 1987b). Too much direct light might cause an explosive growth of algae.

Figure 4: *Aldrovanda* in cultivation. Accompanying plants are *Carex* sp., *Menyanthes trifoliata*, *Phragmites australis* and *Thelypteris palustris*. Photo by C. Breckpot.

The water temperature during the growing season must be at least 16°C (61°F) with 32°C (90°F) as a maximum, but ideal temperatures are 23—30°C (73—86°F) (Saito, 1972). The lower the water temperature, the slower the growth, and the carnivorous activity of *Aldrovanda* will be reduced. Prolonged water tempera-

tures of 29—31°C (84—88°F) cause the Waterwheel Plant to flower (Saito, 1972). Prevent overheating by shading; in overheated water algae might become a serious problem. In colder regions the water temperature can be kept high by protecting the container from the wind by insulating or burying it and by covering it with glass.

Aldrovanda prefers clean, yellowish brown, peaty water with low concentrations of nitrogen and phosphorus. Rainwater is fine, if it is not too spoiled. Alternatively one can use deionized or peat-infused tap water (Mazrimas, 1974). A water depth of 20—30 cm is sufficient. To prevent accumulation of nutrients, it is recommended that part of the water be replaced regularly. The carbonate hardness should be kept medium high to high (test kits are available in garden centres and aquarium shops) as it helps to minimise acidity (pH) fluctuations and stimulates the decomposition of organic substances.

Carbon dioxide (CO_2) is a key element for photosynthesis. Shortage of it inevitably leads to meagre growth and eventually death. *Aldrovanda* prefers waters with a high CO_2 concentration. Most carbon dioxide in water is produced by bacteria which are responsible for the decay of organic substances. Therefore, the more comfortable we make life for them, the more valuable gas they will produce. While CO_2 continuously diffuses into the atmosphere and is consumed by terrestrial plants, there should be a steady production to maintain the appropriate concentration. There are several methods to raise CO_2 levels artificially (Wilson, 1995). What are the basic needs of bacterial life? They need oxygen and food in the form of organic material. The main sources of oxygen in water are diffusion from the atmosphere and production by water plants. So it is advisable to grow enough submerged plants in the pond to maintain the oxygen level. Artificial aeration should be applied with care as it not only raises the oxygen level but also lowers the CO_2 concentration.

A thick layer of sand on the bottom of the container forms a stable anchoring base for the accompanying rooted plants. Beneath this a small layer of peat can be useful too. Above the sand comes a layer of half-decomposed (not fresh!) leaves of sedges, *Iris*, reeds, arrowheads or rice grasses a few centimetres thick (Saito, 1972; Haldi, 1974; Hanabusa, 1974; Mazrimas, 1974; Ohtaki & Katagiri, 1974). The plant remains will help to maintain a low pH, keep filamentous algae under control and act as a carbon dioxide and humic acid source. The decomposition of this material gives the water a yellowish brown colour. After some time the layer will become exhausted and must be replaced with new material.

The water must be slightly acidic with a pH between 5.6 and 6.8 (Saito, 1972; Haldi, 1974; Ohtaki & Katagiri, 1974; Mazrimas, 1978). Check the pH regularly. If the water is alkaline, then you have to lower the pH by replacing part of the water and adding new plant remains.

Aldrovanda should not be grown without other plants (Figure 6). The company of other water and marsh plants helps to lower the nutrient levels in the water by direct uptake and by stimulation of the decomposition process. Moreover it has been confirmed experimentally that neighbouring plants influence the growth of *Aldrovanda* in a positive way (Kaminski, 1987b). Sedges, *Iris*, reeds, arrowheads and rice grasses are good companions (Hanabusa, 1974; Ohtaki & Katagiri, 1974).

All small water crustaceans are suitable as prey: Branchiopoda (e.g. *Daphnia* spp.), Copepoda (e.g. *Cyclops* spp.), Ostracoda, etc. Look for a healthy, algae-free mesotrophic pond nearby (hard to find in my neighbourhood!) and fish out a quantity of microfauna. Introduce these organisms into the *Aldrovanda* tank and if the water conditions are right, they will survive and reproduce. Another important role of the microorganisms is to help prevent excessive development of floating algae.

Good indicators of the plant's health are the thickness of its apex (thick, onion-shaped—good; thin—bad), the length of the adult plant (more than 1 cm—good) and the number of branches (few—good; none—bad) (Saito, 1972; Mazrimas, 1978).

Healthy water should be clear, straw coloured, contain a variety of small living microorganisms and be as free from algae as possible.

Algae may endanger your *Aldrovanda*. Weak plants become easily infected and will not survive. If the above mentioned requirements are met, your plants will grow fast enough to withstand algae quite well but this does not mean that nothing should be done about it! Too much algae is an indication of bad water conditions. Of all algae, filamentous algae are probably the worst to beat. Take away as much algae as you can, change one or more water parameters and pray. Addition of chemicals (alum, copper sulphate) only solve the problem temporarily and are not appreciated by the Waterwheel Plant. Water snails can be useful to minimize filamentous algae (Ohtaki & Katagiri, 1974) but some species feed on higher plants like *Aldrovanda*, so be careful.

The best way to propagate Aldrovanda is by stem cuttings a few centimetres in length (Mazrimas, 1978; Slack, 1986). Healthy plants do this work for you by forming numerous offshoots.

Prepare winter buds for prolonged frost periods by insulating the container. Alternatively you can store the turions in the refrigerator at 3—5°C (37—41°F) in cultivation water or in a box filled with live *Sphagnum*.

Check your water and plants regularly, they need a lot of attention! Never add fertilisers (nitrogen/phosphorus/potassium) to the water. Last but not least, do not give up too fast, finding the right water balance is time-consuming. Good growing!

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ALDROVANDA FROM NORTHERN UKRAINE

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Keywords: cultivation: *Aldrovanda vesiculosa*—ecology: *Aldrovanda vesiculosa*, Ukraine.

Aldrovanda is spread mainly throughout warm and mild climatic zones where the coldest month's average temperature is no lower than -4°C (25°F). It has recently been discovered in the Kiev Reservoir north of the city of Kiev (50° N latitude), and also in the south of Bielorussia. This is interesting because in the northern Ukraine January's average temperature is about -6°C (21°F).

Aldrovanda vesiculosa is reported to be found infrequently throughout the whole Ukraine. In the southern parts of the country it settles in shallow basins in the lower reaches of the Danube and Dnieper Rivers, and in the north it grows in marshy parts of the Shatskiy Lakes, the Kiev and Kremenchug Reservoirs, and in the Pripyat River. *Aldrovanda* has been registered in the Red Data Book of Ukraine and is protected by national environmental law in the Shatskiy and Danube Nature Reserves.

The Kiev Reservoir is situated on the Dnieper River 30 km north of Kiev. The Dnieper's tributaries (the Pripyat River and the Teterev River) also feed the reservoir. The reservoir is 100 km long and has an average width of 8 km, so the entire surface area is 992 km^2. Since its average depth is only 4 meters, the total water volume is 3.7 km^3. Especially shallow water 2.5—3 m deep covers 33—48% of the area and is overgrown with water weeds. The rate of water flow through the reservoir amounts to 9—12 complete exchanges per year. The local climate is moderate, with average annual air temperatures of 6—7°C, and the 500 mm annual rainfall is balanced by the same amount of evaporation. Spring floods begin on March 20—April 15 and stop on June 5—30.

Ice covers the reservoir from December until the middle or end of April (for 2.5—3.5 months). Water temperatures are above 10°C from the middle of April until the end of October, with a maximum temperature of 20—24°C between July and August. The growing period is 6—7 months. Dissolved salts range from 120 mg/l in spring to 380 mg/l in winter. The pH ranges from 6.8—7.2 in winter to 8.0—8.7 in summer.

The *Aldrovanda* population in the upper parts of the Kiev Reservoir was found in 1979 by hydrobiologists V. Gorbik and V. Klokov off Domantovsky island near Zeleny Mis (Green Cape) village. For several years the scientists studied *Aldrovanda* development and its penetration into the communities of other aquatic macrophytes. In their 1985 article, they described the compositions of these communities and collected herbarium specimens from them. They wrote that the plant settles in the open sluggish waters 0.1—0.3 meters deep that had silted sand or peat bottoms.

Usually, *Aldrovanda* grows together with other aquatic plants, including *Salvinia natans*, *Typha angustifolia*, *Hydrocharis morsus-ranae*, *Stratiotes aloides*, *Carex acuta*, and others. Sometimes it grows with another aquatic carnivorous plant—*Utricularia vulgaris* L. A significant increase in the growth of *Aldrovanda* was noted in the Kiev Reservoir during 1979—1981 (Gorbik & Klokov, 1985); it successfully dominated the sunny shallow water areas. They suppose *Aldrovanda vesiculosa* was brought to the Kiev Reservoir from southern Bielorussia by migrating water fowl or by spring floods.

Unfortunately, there is no record about *Aldrovanda* blossoming in the Kiev

Reservoir. Most likely it lacks warmth during its growing season. It is only known that it multiplies vegetatively with the help of its resting buds-which winter on the bottom of the water reserve. Usually in winter all Kiev Reservoir gets thickly covered with ice while its shallow areas get frozen through to the very bottom. Nonetheless, the *Aldrovanda* resting buds winter successfully and start growing late April—early May.

In spring 1995 a few specimens of *Aldrovanda* from Kiev Reservoir were given to me for study (through my collegues at work). I placed them in a water tank with low plastic walls and put it in a well sun-lit place. Twice a month I added chlorine-free potable tapwater and rainwater (about 50% of each). As fodder, I used home-cultivated small crabs (Cladocera family)—*Ceriodaphnia dubia* and *Moina* sp. For three months all specimens grew and multiplied, producing branch plants.

Unfortunately, all specimens of *Aldrovanda* given to me were infected with some small pests which developed on their leaves, causing accelerated death of its aging parts. At the end of summer after my three-weeks' absence I found out that *Aldrovanda* were completely veiled by the parasites, as if by a spider web. I decided against fighting the water-weeds and let *Aldrovanda* grow in a small woods pond in a marshy territory where *Utricularia vulgaris* grew successfully. Time will show if *Aldrovanda* survived in a new surrounding.

From my own short experience in *Aldrovanda* cultivating I can give some tips:

1. Inspect thoroughly all specimens of *Aldrovanda* if transplanting them from natural environments into culture. If pests develop, remove the damaged parts.

2. Keep water tanks with *Aldrovanda* in a warm and well lit place, but shade them from direct sunlight during summer months.

3. Use rainwater (or the equivalent) for cultivation. Add a few lumps of peat for slight acidity.

4. For *Aldrovanda* cultivation use 6—8 liter plastic tanks with a wide bottom and low walls.

5. To avoid competition keep *Aldrovanda* apart from other water plants.

6. As fodder use small crabs such as *Ceriodaphnia* and *Moina* which can be easily grown in a separate small tank.

Unfortunately, during the last three years no hydrobiologists visited *Aldrovanda* habitats in the Kiev Reservoir. I visited the site in June 1997 (Figure 1), found the plants, and collected some new information about its surroundings. This investigation will be continued and I will publish its results.

Figure 1: The author after a successful hunt in the Ukraine.

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How to Grow *Aldrovanda vesiculosa* Outdoors

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Keywords: cultivation: *Aldrovanda vesiculosa*—cultivation: Czech Republic.

Aldrovanda vesiculosa L. (Droseraceae) is a rootless aquatic carnivorous plant. (Figure 1) rapidly vanishing from Europe and possibly also from other parts of the Old World. The protection of this critically endangered species should not only aim at conserving its remaining sites (it does not help much in Europe) but active measures must be accepted as soon as possible. Recently, preparation of sterile tissue culture of *Aldrovanda* was demonstrated, its extensive propagation is on the way, and an experimental selection of suitable substitute sites succeeded in the Czech Republic. However, both approaches require a rich stock culture. Cultivation of *Aldrovanda* has often been described on an empirical basis (Saito, 1972; Haldi, 1974; Hanabusa, 1974; Ohtaki & Katagiri, 1974; Mazrimas, 1974, 1978; and Duval, 1990). Here, a reliable technique of outdoor cultivation of European *Aldrovanda* (from east Poland), based on a study of its ecology at Polish sites, is presented.

Generally, *Aldrovanda* requires warm and clean brownish water with a low mineral nutrient (nitrogen and phosphorus) concentration but a high CO_2 concentration, sufficient prey, and enough light. I cultivate it in a plastic container (1 m^2; Figures 2 & 3) but a small garden water lily pool can also be used. The cultivation technique very much resembles that described by Hanabusa (1974) and reminds me of the character of the species' richest natural habitats in Europe. The suitable substrate must be rich in organic matter but poor in mineral nutrients. A thin layer (ca. 0.5 cm) of brown mud from a swamp or gardener's peat placed on the container bottom is topped by a 6—8 cm layer of washed sand or gravel. The thin layer of mud or peat on the bottom is not necessary and only supports the growth of emergent vegetation. Small plants of common reed and the sedges *Carex rostrata* or *C. gracilis* were loosely planted in the sand. The plants affect the cultivation medium like added litter and moderate light. Litter from those sedges is the best substrate; litter of other sedges or common reed may also be used. This litter has similar properties as rice straw, widely used by the above authors. An optimum litter layer is 2—3 cm thick. New litter should be dipped in warm water for several hours to wash out excessive tannins. The litter is a key component for *Aldrovanda* cultivation: it decomposes slowly, continuously releasing humic acids and tannins which are necessary for its growth and development and partly checks the growth of filamentous algae. Furthermore, the litter gradually releases mineral nutrients and CO_2 by its decomposition and keeps the pH between 6.8—7.4.

I emphasize that a high CO_2 concentration (above 0.1 mM, i.e. 4.4 mg l^{-1}) in water is necessary for vigorous growth of *Aldrovanda*. As CO_2 concentration and pH are closely interrelated, a lowering of pH leads to an increase in free CO_2 concentration. However, pH itself is not too important as *Aldrovanda* can grow well within the pH range of 4.0—7.8, the optimum being between 6.0—7.2. Any tap water may be used as the plant is very tolerant of carbonate hardness (i.e. HCO_3^- concentrations of 5—300 mg l^{-1}). The optimum water colour is that of a 3—5 times diluted light ale. When the water is too dark "mirrors" of oxidized tannins are formed on the water surface and *Aldrovanda* plants are short. In this case, removal of a part of the litter and a partial exchange of the water help immediately. As shown in

Table I, the cultivation water was rather poor in mineral nutrients (NO_3^-, NH_4^+, HPO_4^{-2}) which controls algal growth. However, zooplankton must occur in the water to support plant growth. Ostracods and chydorids usually reproduce spontaneously in the brown water. If so, zooplankton does not need to be added. It is also convenient to add some species of water snails that do not graze on higher plants (e.g. *Planorbis*). They also graze on filamentous algae and the smallest snails are very often trapped by *Aldrovanda* plants. The optimum water depth is 20—30 cm.

The optimum temperature for the growth of European *Aldrovanda* is 25—28°C. Temperatures up to 33°C are tolerated but higher ones are not suitable. Obviously, high temperatures of 29—31°C are required to induce flowering. Night water temperature should be 6—10°C lower than the day temperature. To avoid overheating and algal growth during a hot summer, additional shading of the container is necessary, especially in subtropical countries. There, it is also possible partly to bury the container in the earth for its cooling. *Aldrovanda* is photophilous but shading to 30—60%, temporarily to 20%, of full sunlight is useful in summer. As seen in my photographs, some floating aquatic plants (*Hydrocharis morsus-ranae*, *Stratiotes aloides*, *Salvinia spp.*) may also be loosely planted to shade the water and take up excessive mineral nutrients. Their density must be controlled. A partial exchange of old litter with new, and removal of dead plant residues suppress the growth of algae. Indoor cultivation of *Aldrovanda* is rather difficult.

Healthy *Aldrovanda* plants are 8—20 cm long, richly branched with 5 mm traps, and propagate fast. One plant (from a turion) can give rise to 15—30 daughter plants over one season. Overwintering of the European plants is quite easy in the temperate zone with cold winters, but may be difficult in subtropical countries. As a result of the long-term decrease in water temperature below about 16°C, rhomboid turions which are 6 mm long start to develop at the end of September. They become fully ripe in October, probably only in light and cold water below ca. 8°C, when the shoots have decomposed. In countries with a regular ice cover, clean turions should be stored in the cultivation water in a refrigerator at 3—5°C and the outdoor container should be emptied. In regions without ice formation, if the turions are not distinctly formed, it is better to let them float on the water in the container over winter. In April, the old litter must be removed and new litter added, and the container may again be filled with water but the sinking of the turions to the litter on the bottom should be avoided.

As a result of the extremely hot summer of 1994, 138 plants flowered and 17 of

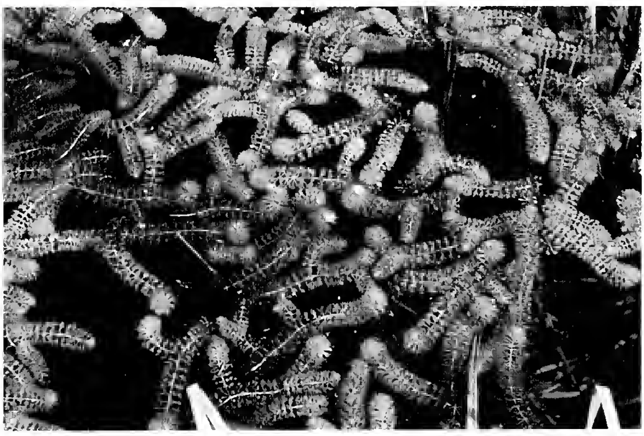

Figure 1: *Aldrovanda vesiculosa* flowering in cultivation. The flowers are 6—7 mm in diameter, July 1994. Photograph by L. Adamec.

Figure 2: Outdoor cultivation of *Aldrovanda vesiculosa*, July 1993. Photograph by L. Adamec.

them even produced seeds. The same cultivation technique may be used to all aquatic *Utricularia* species.

Throughout the 1994-1996 growing seasons, the plants suffered from a disorder. Shoot apices stopped growing as early as in the middle of June and were small, yellowish, flat, and were without typical bristles. As the disorder progressed, the apices became brown and began to die. Damaged plants produced non-functional turions. This disorder has not been observed in naturally occurring plants. Moreover, damaged plants became healthy very quickly once placed in natural habitats. Since no parasite was ever observed in the damaged apices, it was evident the disorder resulted from a mineral nutrition problem, namely a Boron deficiency. After H_3BO_3 was added to the culture medium (0.6 mg l^{-1}), plant growth resumed after a few weeks and the shoot apices returned to good health. It is presumably possible to prevent the disorder by adding a greater amount of clay to each container, since a variety of micronutrients, including Boron, will be continuously released from this substrate. At the first sign of the disorder, it is recommended to add H_3BO_3, striving for a final concentration of 0.5 mg l^{-1}.

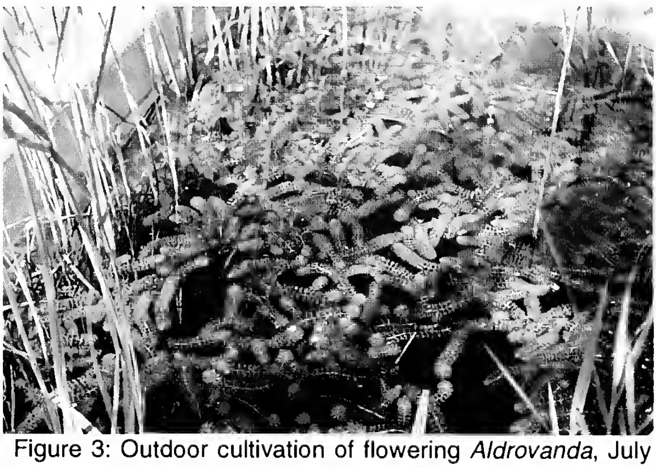

Figure 3: Outdoor cultivation of flowering *Aldrovanda*, July 1994. Photograph by L. Adamec.

Table I: Water chemistry in the container with flowering *Aldrovanda*; summer 1994.

Date	NO_3-N ($\mu g\ l^{-1}$)	NH_4-N ($\mu g\ l^{-1}$)	PO_4-P ($\mu g\ l^{-1}$)	K ($mg\ l^{-1}$)	Ca ($mg\ l^{-1}$)	Mg ($mg\ l^{-1}$)	Humins ($mg\ l^{-1}$)	O_2 ($mg\ l^{-1}$)	HCO_3^- ($mmol\ l^{-1}$)	CO_2 ($mmol\ l^{-1}$)	pH
26 July	4	34	10	1.58	17.9	4.5	26.8	6.4	1.03	0.23	7.0
15 Aug.	0	22	12	0.18	19.5	5.3	—	11.2	1.20	0.11	7.4

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Conservation of Endangered *Aldrovanda vesiculosa* by Tissue Culture

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Keywords: conservation: *Aldrovanda vesiculosa* — cultivation: *Aldrovanda vesiculosa*, tissue culture.

According to the literature, *Aldrovanda vesiculosa* L. is distributed widely throughout the Old World and Australia (e.g., Diels, 1906; Marchant *et al.*, 1982). But in reality it has become endangered, and some of its local races are extinct. It is extinct in Bangladesh, Denmark, France, Germany, Italy, Japan, and other places. Meanwhile, it is endangered in Poland, Switzerland, and vulnerable in Bulgaria, China, Croatia, the Czech Republic, Hungary, and Russia. Not much information is available for its other sites.

Its history in Japan is a fine example of its plight. Japan used to have ten localities of the species, which disappeared one by one. The last Japanese race grown in Houzouji Pond (approximately 3 hectares, or 7.4 acres) in Hanyu City, Saitama Prefecture, has been protected by the Cultural Properties Protection Law #214. As a national natural monument it has been regulated by the Culture Agency of the Ministry of Education, Science, Sports and Culture of Japanese Government since 1966 (Hanyu City Education Commission, 1982; Komiya, 1989). However, in 1966 Typhoon #14 damaged Houzouji Pond. Subsequent eutrophication resulted in the plant's disappearance. This would have resulted in the extinction of the last Japanese *Aldrovanda vesiculosa*, but fortunately plants were being cultivated by biology clubs of local high schools. The plants were later reintroduced to their so called natural habitat when it was artificially restored. They have since been continuously protected as a national natural monument.

Aldrovanda vesiculosa in Italy also became extinct and survives only in cultivation (Henriquel, 1997). In Bangladesh *Aldrovanda vesiculosa* disappeared in monsoon floodwaters prior to 1991 and is now extinct (Khan, 1990; Kondo, 1995).

Although *Aldrovanda vesiculosa* has a wide distribution, little gene flow may occur between populations since its locations are small, well-isolated areas distant from each other. The local races of *Aldrovanda vesiculosa* must be given much more attention and need to be monitored for conservation. The species has not been listed in CITES Appendices.

Can tissue culture save endangered *Aldrovanda vesiculosa*?

Most plants which may reproduce by self fertilization or vegetative reproduction may be easily conserved in the laboratory without any concern for critical population size or genetic diversity, while plants which require cross fertilization may not (Kondo, 1996). The self fertilizing species might eliminate bad or lethal genes

during their evolution and might not have inbreeding depression. They could have limited genetic variability. Since the majority of their alleles could be nearly or completely homozygous, these plants need only a few strains per race to be conserved in the laboratory (Kondo, 1996). Even one strain may be sufficient. *Aldrovanda vesiculosa* is a self fertilizing and vegetatively reproducing species, and thus is an excellent candidate for conservation in a small laboratory space using tissue culture methods.

In tissue culture, the shoot primordium, multiple shoot, and somatic embryo methods (without plant hormone supplements) are effective with *Aldrovanda*. These methods may be useful and safe for micropropagation and gene conservation of inbreeding species. This is because they do not induce genetic mutation in the culture for a long time (nearly 0% aberration in well selected and purified culture cells). In contrast, the callus and cell suspension method (with some plant hormone supplements) may have these problems.

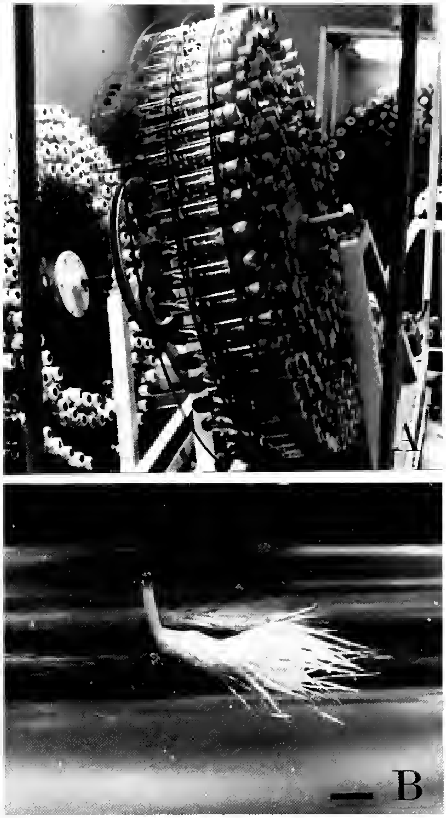

Figure 1: *Ex situ* conservation of *Aldrovanda vesiculosa* in the laboratory. A) A rotary culture apparatus provides the necessary environments for axenic and tissue culture. B) Axenic seed germination. An ovoid seed with a black, smooth seed coat germinated with a root which stopped growing when it was less than 1 mm long. It had a red root tip, filiform cotyledons, and true leaves in bud. Bar=1 mm.

Axenic seed germination

Polish race seeds of *Aldrovanda vesiculosa* (1.0—1.5 mm long, ovoid, with black, smooth seed-coats) were collected and surface-sterilized with 1% (v/v) benzalkonium chloride for five minutes, 1—2% (v/v) sodium hypochlorite solution for five minutes, followed by 70% ethanol for a few seconds. After rinsing in sterilized, distilled water 3—4 times, the seeds were first planted and cultured in Gamborg's B5 liquid medium (Gamborg *et al.*, 1968) supplemented with 2% sucrose, gibberellic acid at the final concentration of 20-50 mg l^{-1}, some drops of penicillin and streptomycin at pH 5.5 in flasks for a day for perfect sterilization and to provide germination stimuli. Then, each seed was transplanted and cultured in 25 ml of B5 liquid medium supplemented with 2% sucrose at pH 5.5 in test tubes (30 mm diameter × 200 mm long). The test tubes were shaken at a rate of 2 cycles per minute on a rotary culture apparatus (Figure 1A) at 22°C under 2,000—10,000 lux continuous illumination provided by a halogen lamp. After a week or so, 60% of the seeds sown germinated without any contamination by fungi, bacteria or viruses. The germination pattern in the *A. vesiculosa* seed is documented here for the first time.

1. A root arose from the hilum of the seed and stopped growing when it was less than 1 mm long. The color of the pin-point root tip changed into red.
2. The filiform cotyledons and true leaves were produced, forming a seedling (Figure 1B).
3. The seedling grew to the mature stage.

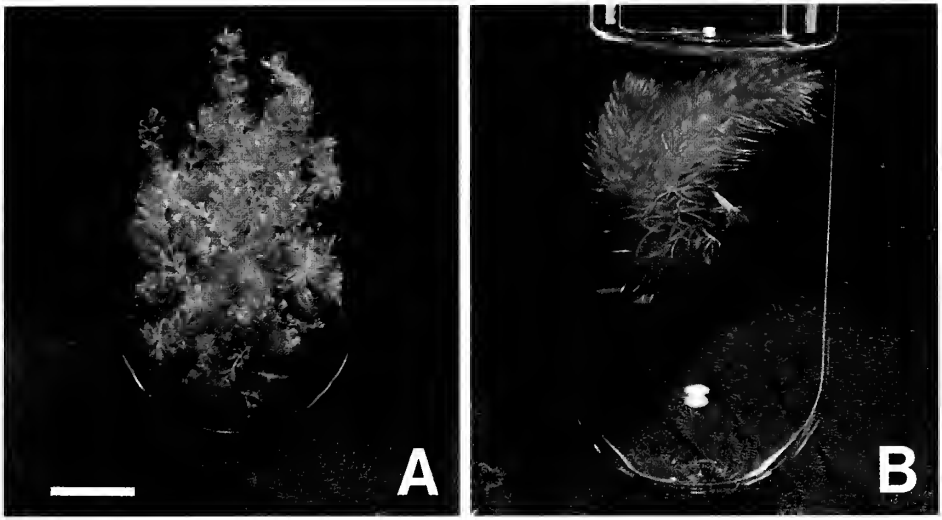

Figure 2: Tissue culture of *Aldrovanda vesiculosa* in B5 liquid medium. Bar=1 cm. A) Hanyu race. The cultures micropropagate rapidly by multiple shoots, but the shoots are small and slender. B) Polish race. The cultures form a shape like raccoon tails and branch once or twice per month. These two races were different in growth habit, even in the same medium and environment.

Tissue culture

The Hanyu race of the Japanese *Aldrovanda vesiculosa* was chosen for this experiment. It was quite difficult to sterilize shoot tips of the *Aldrovanda vesiculosa* plants *in vivo* because they contained numerous aquatic microorganisms such as water mold, bacteria, virus and so on in their intercellular spaces. After many sterilization failures of shoot tips, midwinter buds were chosen and their shoot tips were successfully surface-sterilized by the procedure described above for the primary culture. Then, multiple shoots were induced and subcultured in B5 liquid medium supplemented with 2% sucrose at pH 5.5 under the culture environment described above. These multiple shoots became dwarfish and slender and excellent form to fit to small and narrow test tubes. They proliferate so rapidly they fill a 25 ml volume within a month (Figure 2A). At present we have been maintaining more than 2,000 individuals of the Hanyu race. On the other hand, the mature plants of the Polish race were subcultured using in the same method and culture environment described above (Figure 2B). But, they have never differentiated into multiple shoots and never dedifferentiated into shoot primordia or other cultures. The plants continuously grew to form shapes like raccoon tails, and branched once or twice per month. Branched stems were cut, artificially divided and transplanted to other test tubes for propagation. The growth form of the Polish race is quite different from that of the Hanyu race, perhaps due to genetic diversity among the world races. At present we have more than 200 individuals of the Polish race.

Acclimatization

In vitro cultures of *Aldrovanda vesiculosa* can be rather easily acclimatized in outdoor environment: they are washed and rinsed well by tap water to remove B5 medium and sucrose before they are placed into tap water for two to three days. Then, they are cultivated in water soaked rice stems (which were first dried) and planted with aquatic plants such as *Iris*, rushes, and cattails in small containers during the spring season.

A rescue center for *Aldrovanda vesiculosa*

Aldrovanda vesiculosa is a relict species and is sensitive to acid rain, eutrophication, floods, and other human disturbances. Several local races of the species have already become extinct and more races may disappear soon. Since we find that each race seems to have a different genetic composition, a vigorous race obtained in a site and propagated by tissue culture must be reintroduced to the same locality. It should not be reintroduced to a different site, otherwise the genetic constitution of the world's *A. vesiculosa* populations would be contaminated. Each race must be separately isolated and tissue cultured to increase the gene bank's genetic diversity. The Laboratory of Plant Chromosome and Gene Stock at Hiroshima University is the nominee for the gene bank of *Aldrovanda vesiculosa*.

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Fossil *Aldrovanda*

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Keywords: evolution: *Aldrovanda*.

Aldrovanda vesiculosa L. is one of the most widespread but rarest carnivorous plants. It is a sure bet that few of you have ever seen it, let alone successfully grown it. This aquatic possesses the same kind of sophisticated traps as its larger and better-known relative, *Dionaea muscipula*. Are these incredible leaves the latest, most recent development in arthropod-catching strategies?

The answer is no, as shown by the fossil record. Some seed fragments from a species named *Palaeoaldrovanda splendens* were found in the south of the Czech Republic (Knobloch & Mai, 1984, 1986). They date from the end of the Cretaceous period (Senonian epoch, 85—75 MYA[1]), and are the oldest known remains of a carnivorous plant! But this does not mean that *Aldrovanda* is the oldest carnivorous genus—for example it is noteworthy that the Australian sundews possess similar tentacles. This proves that *Drosera* traps are at least as old as the separation of Australia from the other continents (which occurred during the late Cretaceous period to Eocene epoch) even if no pre-Tertiary sundew fossils have been found anywhere.

Palaeoaldrovanda grew on tropical islands inhabited by smallish Dinosaurs, which characterized the geography of Europe during the Cretaceous. Ten million years after the Senonian epoch, the world was hit by a wave of mass-extinctions. The Paleocene (65—55 MYA) was the first epoch of the Tertiary period. The living world slowly recovered from the mass extinctions under a markedly cooler climate. Some *Aldrovanda* pollen from Germany may date from this time (Krutzsch, 1970a), the first sign that this tropical genus was able to withstand less favorable conditions.

In contrast, the Eocene (55—38 MYA) was an epoch of uniformly warm climates. Conditions in western and central Europe were much like those in present day Malaysia. As could be expected, our sun-loving *Aldrovanda* species prospered. Not one, but several species appear to have existed (Figure 1). *Aldrovanda* seeds (*A. ovata* and possibly already *A. intermedia*) have been recovered from geological layers from this age on the Isle of Wight and in the Hampshire Basin in south England (Reid & Chandler, 1926; Collinson, 1990). Krutzsch (1985) mentions Eocene epoch seeds from the Weissel Basin in eastern Germany. Pollen, another type of fossil, has been recovered from three areas: *Saxonipollis saxonicus* (An extinct plant, possibly a precursor to *Aldrovanda*, or a close relative of this precursor—ed.) from eastern Germany (Krutzsch, 1970a), a similar type from the early Eocene of Belgium (Krutzsch & Vanhoorne, 1970; Krutzsch, 1970a), and finally Kazakhstan (west Siberia) with pollens of two size classes (Table 1). Although smaller and larger grains are also known in the case of *Saxonipollis* (Krutzsch, 1970a), the Siberian pollens have been described as belonging to two distinct species: *A. unica* and *A. kuprianovae* (Kondratiov, 1973).

These are fossils from seeds and pollen: but what did the plants that produced these look like? We have no idea, and it is very improbable that leaf fossils from

[1] MYA means Millions of Years Ago, and notes the age of a fossil or geologic time period.

Aldrovanda will ever be found. Dried plants from this species are feather-light. Most of the fresh weight is water, and there is hardly enough dry matter to allow their preservation as fossils. All one can say is that, judging from the accompanying flora, prehistoric *Aldrovanda* already inhabited wetland areas (Mai, 1985). They grew in biotopes comparable to the modern ones: bogs in the middle of pine woods and reed marshes (Schneider, 1990), temporary ponds in dry areas—not deserts as in what is now sub-Saharan Africa (Collinson, 1990) or coastal swamps (Friis, 1975). If they were aquatic, the ancestral waterwheel plants could hardly have possessed sticky traps. If they had any traps at all, the best guess is that these were similar to those of the modern species.

The Eocene epoch fossil finds from England and Belgium lie well outside the present range of the species. The presence of seeds and pollen implies that *Aldrovanda* did produce flowers in these sites. Present conditions are not good enough for it to do so anywhere in Europe, where it is said to only reproduce vegetatively. So the real range during the Eocene may have been even larger than we can tell from fossils!

Based on seed size and the symmetry and prominence of the germination cleft, the genus *Aldrovanda* has been divided into three sections: Aldrovanda, Obliquae and Clavatae (Dorofeev, 1968; Mai, 1985; Iakubovskaya, 1991). One cannot say whether this has any bearing on what the various species looked like. (Drawings of seeds are shown in Figure 2.) The distinctions between species have also been criticized (Friis, 1980). Recent scanning electron microscope investigations of the seed structure seem to confirm the existence of different species (Iakubovskaya, 1991). There is also often an uncertainty in determining the ages of the geological layers where the fossils are found. So the phylogenetic tree of *Aldrovanda* is still rather fuzzy.

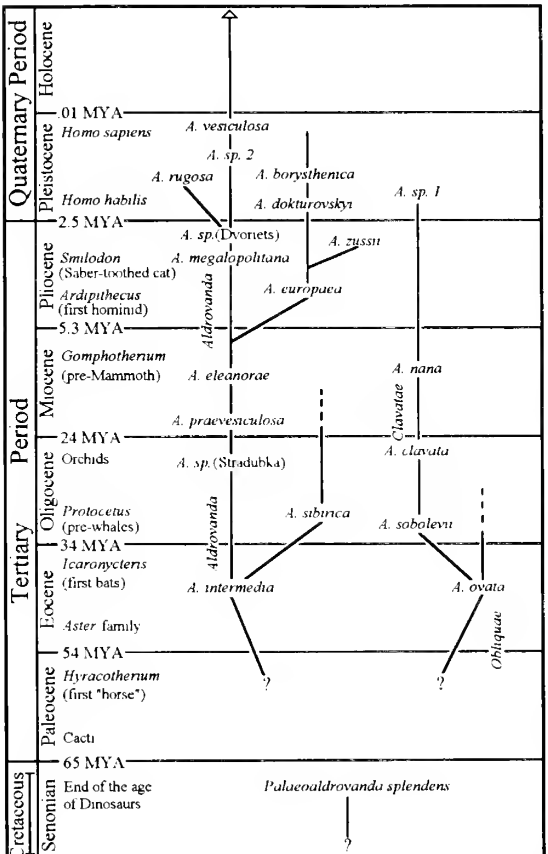

Figure 1: The evolution of Aldrovanda may be inferred from seed fossils. Many species existed in the past. This figure was created by B. Meyers-Rice and J. Schlauer. For the sources consulted, see the figure references.

During the following epoch, the Oligocene (38—22 MYA), the climate became cooler and drier. Curiously, the tropical waterplants appear to have been less sensitive to these changes than their terrestrial counterparts (Mai, 1985). Oligocene Europe harbored *A. intermedia* (south England: Reid & Chandler, 1926; eastern Germany: Walther, 1990), and west Siberia had A. *sobolevii* (Dorofeev, 1968). This pair of related plants is one of many which prove the existence of contacts between these two regions (Mai, 1985).

The Miocene epoch (22—5 MYA) was characterized by alter-

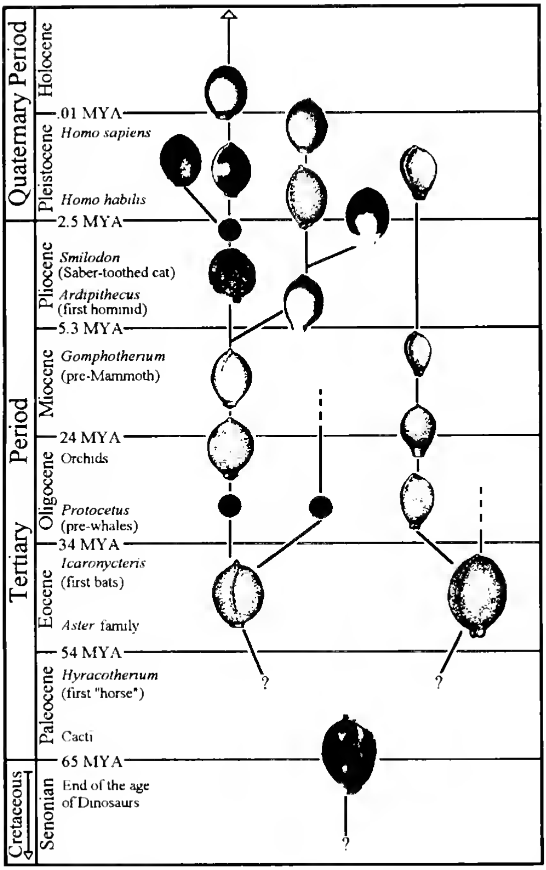

Figure 2: Drawings of seed fossils assembled by B. Meyers-Rice and J. Schlauer. The placement of fossils on this figure follow Figure 1. Black disks were used where no drawings were available. See figure references.

nating much cooler and slightly warmer periods, more so in western Europe than in Kazakhstan (Mai, 1985). It is astonishing how some representatives of the Palaeotropical flora, including *Aldrovanda*, manage to occur in Europe tens of millions of years after the tropical landscapes that were their true setting had vanished. The fossil seeds seem to indicate three species: *A. praevesiculosa* (Germany: Kirchheimer, 1941a; Noetzold, 1961; Denmark: Friis, 1975, 1980, 1985; Poland: Raniecka-Bobrovska, 1959), *A. nana* (Bielorussia: Dorofeev, 1960) and *A. clavata* in Kazakhstan (Dorofeev, 1963). Fossil pollen, maybe from one of these species, was found in the southern Ural (Cigurjajeva, 1956, cf. Krutzsch, 1970a, p. 421).

A. praevesiculosa was still found in the late Miocene (Palamarev, 1990) and Pliocene epochs 5—7 MYA) of Bulgaria (Palamarev, 1970). West Siberia harbored *A. eleanorae* (Nikitin, 1957), and contained *A. europaea* (Iakubovskaya, 1991).

The Pleistocene epoch glaciations meant a new and severe strain on the *Aldrovanda* populations. So you would expect to find fewer species? Wrong! What one actually witnesses is a staged extinction of the genus. Isolated sanctuaries in southern Russia and in the Ukraine allowed the formation of local species (Velichkevich, 1990a). During interglacial periods these reoccupied the areas lost, only to be killed off during the next glaciation. Newly evolved species replaced them when temperatures rose again. This makes *Aldrovanda* a very useful marker for dating soil samples, and for that reason the species is well known to paleobotanists. For example, the sediments from three interglacial periods from Bielorussia contain fossils of *A. sp.*, *A. borysthenica* Wieliczk and *A. dokturovskyi* Dorofeev respectively (Velichkevich, 1990b). A few other species from the same area have been described recently: *A. zussii*, *A. rugosa*, and two unnamed ones (Iakubovskaya, 1991).

At present the southern continents Africa and Australia are in contact with Eurasia. They have been colonized by the species that is typical of the interglacial period we live in. That is also shown by the fossils that date from since the upper Pleistocene (Kirchheimer, 1941b; Hartz, 1909, see Friis, 1980), namely *Aldrovanda vesiculosa*. As it does occur in tropical areas, the genus seems safe from extinction.

Even though human activities are rapidly causing it to disappear from Europe and Japan, the sites in Africa and North Australia do not seem to be threatened by mankind. Perhaps this is where the species will survive future environmental changes. So the sad story of *Aldrovanda*, with its more than twenty extinct species, still ends on a rather positive note!

Acknowledgements: many thanks to Dr. Knobloch from Prague, for providing difficult to obtain papers, and to Ludek Frkal for translations from the Russian.

Table 1: Fossil *Aldrovanda*: Tertiary Pollen

Epoch	Taxon
Miocene	*A. sp.* (south Ural)
Eocene	*Saxonipollis saxonicus* (east Germany)
Eocene	*A. unica* (Kazakhstan)
Eocene	*A. kuprianovae* (Kazakhstan)
Eocene	*A. sp.* (Epinois, Belgium)
Paleocene	*A. sp.* (east Germany)

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Fossil *Aldrovanda* — Additions

Dr. J. Schlauer

Keywords: evolution: *Aldrovanda*.

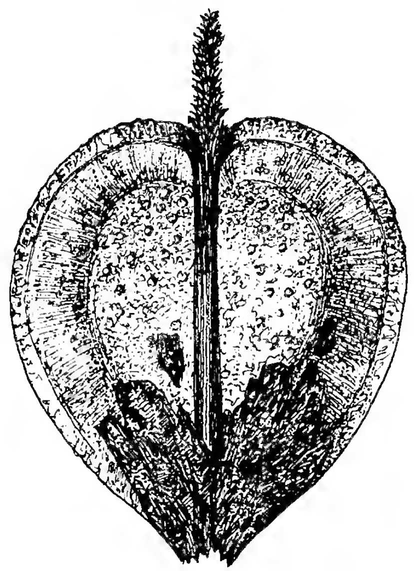
Two articles that appeared in the 1960's are not considered in the previous, otherwise accurate paper by Dr. Degreef. As they contain important additional information they shall be mentioned in brief here.

Weyland, H., Pflug, H. D., Marinos, G., and Anastopoulos, J. 1961, Beiträge zur fossilen Flora des Braunkohlenbeckens von Megalopolis im Peloponnes (Griechenland), Palaeontographica Abt. B Paläophytologie 108: 93-120.

Peters, I. 1963, Die Flora der oberpfälzer Braunkohlen und ihre ökologische und stratigraphische Bedeutung, Palaeontographica Abt. B Paläophytologie 112: 1-50.

The first paper reports on another Tertiary find. Seeds of *A. megalopolitana* are described (on pp. 104—105, t.18 fig. 10—11) from the Pliocene of south Greece. The seeds have a rather thick testa, and especially noteworthy is an interior layer of cells that are stretched at right angles to the longitudinal axis of the seeds. This character is only observed in one other fossil species, viz. the Late Cretaceous *Palaeoaldrovanda splendens* (cf. Dr. Degreef's paper). According to the authors, no other fossil *Aldrovanda* seeds are known in which this cell layer is preserved. For completeness, the species *A. megalopolitana* is included in Figures 1 and 2 of Dr. Degreef's paper.

The second paper is even more intriguing. In this paper (on pp. 29-31, t. 13 fig. 74-76, t. 14 fig. 77-81), fossil laminae of *Aldrovanda inopinata* from the Upper Miocene (approximately 6 MYA) of Wackersdorf (southeast Germany) are described (Figure 1). They are rather similar to the traps of the recent *A. vesiculosa* but differ in their more cuneate base, the longer apical spur with more bristles, the (apparently) missing sensitive hairs in the central portion of the leaves and the (apparently) missing quadrifid trichomes in the marginal zone. It is a pity that this important and rather sensational find is not cited in large portions of the more recent literature dealing with *Aldrovanda* fossils.



Aldrovanda inopinata Peters

Figure 1: *Aldrovanda inopinata* Peters, reconstruction of lamina. Reprinted with permission by Schweizerbart'sche Verlagsbuchhandlung, Stuttgart, Germany.

Flowering of *Aldrovanda vesiculosa* in Outdoor Culture in the Czech Republic and Isozyme Variability of its European Populations

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Keywords: chemistry: plant — cultivation: *Aldrovanda*.

Introduction

Aldrovanda vesiculosa L. (Droseraceae) is a rootless aquatic carnivorous plant which occurs on every continent in the Old World, but which is rapidly vanishing from Europe (Berta, 1961; Huber, 1961; Degreef, 1986; and Adamec, 1995a). The majority of recently studied sites are in Poland (Adamec, 1995a). *Aldrovanda* grows in shallow, standing, dystrophic waters. Both its extreme rarity and difficult cultivation have caused the species to be little studied. Recently, extensive ecophysiological research on *Aldrovanda* (Adamec, 1997, 1996c) has been accomplished in the Czech Republic. Furthermore, an experimental selection of suitable substitute growth sites has been performed (Adamec, 1996b). Both studies required many cultivated plants. However, cultivation of *Aldrovanda* has only been described on a rudimentary level (e.g., Hanabusa, 1974; Pietropaolo and Pietropaolo, 1986) and no data on water chemistry have been published.

European temperate-zone populations of *Aldrovanda* flower very rarely in natural sites (Berta, 1961; Degreef, 1986; Teryokhin, 1986) whereas subtropical populations flower richly and bear seeds frequently (Pietropaolo and Pietropaolo, 1986; Nakano, 1992). In the Institute of Botany at Wroclaw University, Poland, herbarium specimens with flowering *Aldrovanda* from the following European countries are deposited: south Poland (five sites in Silesia), north and northeast Italy, Romania (Danube delta), Serbia (Yugoslavia), and northeast Turkey. The plants have also flowered in north Russia near Lake Ladoga (Afanas'ev, 1953), in the northwest tip of Ukraine (Teryokhin, 1986), in east Slovakia (Berta, 1961; Studnicka, 1984), south Bavaria, Germany (Huber, 1961), southwest France, and in central Italy (Caspary, 1862, cit. Degreef, 1986). *Aldrovanda* was rarely observed to flower in nearly all European countries of its former distribution. However, fruits and seeds usually fail to develop in flowering plants in Europe (Caspary, 1862, cit. Degreef, 1986; Teryokhin, 1986). The European plants of this species have never flowered in cultivation (Studnicka, 1984).

The origins of Eurasian temperate populations of *A. vesiculosa* and their relationships to tropical African ones are still controversial (Berta, 1961). On the basis of palaeobotanical findings and turion formation, this species is considered to be a Tertiary relict in the European flora (Berta, 1961; Degreef, 1986). The European distribution of *Aldrovanda* was highly discontinuous, occurring in small isolated patches, scattered or grouped together. *Aldrovanda* is spread by migratory water birds and this may explain why its former European distribution overlapped with main migratory routes of water birds (Berta, 1961).

In this paper, characteristics of the flowering plants of European *Aldrovanda vesiculosa* in outdoor culture in Trebon (latitude 49^{o} N, Czech Republic) are presented. Isozyme variability among four European populations is also compared.

Materials and Methods

Aldrovanda was collected in east Poland in June 1993. To maintain the plants in cultivation, conditions existing at the species' most prolific natural sites in Europe were mimicked (Adamec, 1995a). These conditions resembled those described by Hanabusa (1974). Cultivation techniques are fully described in another paper in this issue of CPN (see p85-88).

Aldrovanda plants of three other European populations (northeast Poland; Switzerland, here introduced from Lake Constance in south Germany; and Italy, possibly Lake Sibolla near Lucca in central Italy) were cultivated outdoors in aquaria three to twenty liters in size. The aquaria, covered by glass panes, stood in a plastic container (2.5 m^2) filled with 0.6 m of water to provide cooling. Water in the plastic container was stirred by bubbled air throughout the summer to prevent the aquaria from overheating. In addition, the aquaria were also shaded by plastic foil. The water levels in the aquaria were maintained 1—2 cm lower than that in the plastic container.

Flowering cultivated plants were investigated from July to September 1994. At the beginning of flowering (July 23), all fifty flowering plants (out of a total of 250 plants) were analysed. For each plant, measurements were made of the total length, the number of adult leaf whorls on the main shoot, the number of flowers and flower buds, and the number of shoot branches. The total length of each flower stalk was measured only in fully developed flowers or those in subsequent stages of capsule development.

At the peak of plant flowering (August 15), the number of flowers and fruits including flowers damaged by parasites were estimated in all 138 flowering plants (out of about 500 plants). Four categories of flower and fruit development were defined: A—young flower buds with stalks shorter than 1 cm; B—flower buds with stalks longer than 1 cm and flowers just before opening or fully opened; C—young green capsules with green sepals; D—old brownish capsules with brownish sepals (evidently abortive capsules). On September 28, twenty-one fertile capsules were harvested and the numbers of seeds were estimated.

Polyacrylamide gel electrophoresis (PAGE) has been used according to Kirschner *et al.* (1994); for systems of enzyme detection see Vallejos (1983) and Kirschner *et al.* (1994). Adult plants of *A. vesiculosa* were hand-cleaned of filamentous algae and prey carcasses in traps. The apical shoot segment (1.5 cm long, fresh weight approximately 70 mg) of each plant was ground in an ice-cold extraction buffer. Crude homogenates were centrifuged at 20,000 rpm for ten minutes. The clear supernatant was immediately subjected to gel electrophoresis.

The following enzyme systems were investigated: malate dehydrogenase (three loci), NADH dehydrogenase (five loci), alcohol dehydrogenase (two loci), glutamate dehydrogenase (one locus), phosphogluconate dehydrogenase (two loci), aspartate aminotransferase (two loci), and phosphoglucomutase (one locus).

Results and discussion

Temperature maxima in the cultivation medium close to the surface was usually 26—32°C during July 1994, which induced prolific flowering. Temperatures fell to 14—23°C in September but the plants still flowered and produced new flower buds. On the basis of 1994 and 1995 seasons, the minimum afternoon water temperature needed to induce flowering in *Aldrovanda* from east Poland may be assumed to be 26—28°C for 2—3 weeks (cf. Studnicka, 1984; Degreef, 1986). Presumably, good CO_2 content in the water, prey availability, and irradiance of 40% full daylight or greater are other requirements for flowering.

The first flower buds appeared on July 19, 1994, and opened flowers were observed from July 22 until September 19. The flowering plants were usually 7.8—9.9 cm long and all were branched (Table 1). The branches prevented the shoots with flowers from rotating and stabilized the opened flowers above the water sur-

face. The adult flower stalks were only 1.4—1.6 cm long. The diameters of fully opened flowers were 6—8 mm. At the end of July, the majority of flowers opened while only a minor number did at the end of August and September. Most of the tardily developing flower buds did not ripen. As observed by Berta (1961) in east Slovakia, *Aldrovanda* formed chasmogamous (i.e., opened) flowers only under optimal habitat conditions and cleistogamous (closed), abortive flowers under suboptimal ones. In our cultivation, the flowers opened shortly for only two to three hours, between 3:00 p.m. and 6:00 p.m. The opened flowers floating on the water surface were susceptible to soaking. Caspary (1862, cit. Degreef, 1986), however, reported that the flowers in Poland opened from 7:45 am to 7:00 p.m. How pollination of the flowers occurs is unknown (Pietropaolo and Pietropaolo, 1986). In our culture, self-pollination rarely took place (and probably only in chasmogamous flowers). The low pollination efficiency is probably due to the short time during which the flowers are opened, and their susceptibility to soaking.

At peak flowering (August 15), all 260 flowers at various stages of development were analysed (Table 2). The mean number of flowers per plant was 1.88 with a maximum of five. Eighty-nine percent of the plants bore one to three flowers. Degreef (1986) reported a maximum of three flowers per main shoot. This value reflects not only the number of flower buds per inflorescence, but also the rates of shoot growth and decomposition. On August 15, all stages of flower development were present nearly evenly, with slightly more adult flowers just before or after opening (Table 2). Parasitized flowers occurred most often in the old abortive capsules. The agents were probably diminutive insect larvae.

Of all flowers, only twenty-one capsules bore seeds. The abortive capsules were brownish and bore soft abortive ovules around 0.6 mm long. The capsules with ripe seeds (length 4.0—5.5 mm, width 3.0—4.0 mm) were considerably larger than the abortive ones, turgid, and kept their green colour till the end of September. They contained one to nine hard seeds 1.2—1.4 mm long (mean 4.0 seeds per capsule, median 3.0, quartils 2.0—6.0). The black glossy seeds sink in water. Teryokhin (1986) described 1.5 mm long seeds from northwest Ukraine. Nakano (1992) reported one to seven seeds per capsule in Japanese plants. Although the seeds of European plants may also germinate (Degreef, 1986; Teryokhin, 1986), the germination of seeds is very rare in Europe, but quite common in subtropical or tropical countries (Nakano, 1992). Heat and light promote their germination (Degreef, 1986; Nakano, 1992). In twelve seeds of our harvest, half germinated within one year (Pásek, 1995).

Isozyme analysis of populations from northeast and east Poland, Italy, and Germany revealed no variability within or among populations in fifteen of sixteen loci of the seven enzymatic systems tested. However, one NADH dehydrogenase locus was missing in all samples from a northeast Poland population. Although only 5—20 plants were analyzed from each population, no observed isozyme variability within these populations may indicate their clonal character with lack of generative reproduction. The homogeneity found among distant populations (1,300 km between central Italy and east Poland) indicates that most recent European populations of *Aldrovanda* have a common origin. The present distribution is a mere fraction of the historical one (Adamec, 1995a; cf. Berta, 1961; Huber, 1961). We may speculate that the lack of genetic variability of *Aldrovanda* in Europe is caused by the isolation of these marginal populations with little or no contact with the probably more diverse subtropical and tropical populations.

Acknowledgments

The paper is dedicated to Dr. Donald E. Schnell on the occasion of his twenty-fifth anniversary of editing Carnivorous Plant Newsletter and for his whole life study and popularization of carnivorous plants. Thanks are due to Dr. Ryszard Kaminski from Wroclaw University, Poland, for kindly providing the herbarium data and to Stewart Hanson (Arizona, USA) for the language correction. This

research was granted by the Academy of Sciences of the Czech Republic (project No. 605401).

Table 1. The characteristics of fifty flowering *A. vesiculosa* plants on July 23, 1994. The number of adult leaf whorls in the main shoot is given. The numbers of shoot branches, flowers and flower buds are expressed per plant.

	Median	Quartils	Mean	Range
Main shoot length (cm)	8.7	7.8—9.9	9.0	6.1—15.6
Number of leaf whorls	18.0	17—20	18.8	13—27
Number of shoot branches	1.0	1.0—1.0	1.2	1—2
Number of flowers and buds	1.0	1.0—1.0	1.02	1—2
Adult stalk length (cm)	1.5	1.4—1.6	1.55	1.2—1.9 (n=19)

Table 2. The characteristics of 138 flowering *A. vesiculosa* plants on August 15, 1994. (A) number of plants with the given numbers of flowers and flower buds expressed in % of all 138 plants; (B) categories of flower development in single plants: I, young flower buds with stalks shorter than 1 cm; II, flower buds with stalks longer than 1 cm and flowers just before or after opening; III, young green capsules with green sepals; IV, old brownish capsules with brownish sepals; (C) relative occurrence of damaged flowers in the four categories.

(A)	Number of flowers and buds per plant				
	1	2	3	4	5
Occurrence	50.0%	23.3%	15.9%	10.1%	0.7%
Flowers/plant: 1.5 (median), 1.0—3.0 quartils, 1.88 (mean).					
(B)	Categories of flower development				
	I	II	III	IV	
Occurrence in plants	40.6%	60.1%	34.8%	31.2%	
% of all flowers	21.5%	33.1%	23.1%	22.3%	
(C)	Categories of flower development				
	I	II	III	IV	
Damaged flowers of all flowers in the category	1.8%	8.1%	5.0%	19.0%	

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(ABSTRACT[1])
PHOTOSYNTHETIC CHARACTERISTICS OF THE AQUATIC CARNIVOROUS PLANT *ALDROVANDA VESICULOSA*

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Aldrovanda vesiculosa L. is a critically endangered aquatic carnivorous plant. It is considered to be strictly stenotopic. Chemical and physical factors were measured *in situ* in *Aldrovanda* stands at eight Polish sites. There, the oxygen concentration usually ranged between 0.25—0.28 mM. There was a very wide range of pH of 5.04—7.60. but with a median of 7.17. The total alkalinity ranged between 0.16—4.2 meq l^{-1} but was mostly within 1.0—2.7 meq l^{-1}. A high CO_2 concentration was typical in all stands; it ranged between 0.14—3.5 mM and was usually within 0.2—0.5 mM. *Aldrovanda* grew in unshaded stands and in areas shaded by emergent vegetation, where only about 18—24% of incident irradiance penetrated to the water surface. *Aldrovanda* can therefore tolerate various levels of oxygen, pH, total alkalinity, and shading but requires a high CO_2 concentration (i.e. above about 0.14 mM). This is the most important condition for its very fast apical growth. Laboratory photosynthetic study revealed that *Aldrovanda* was a strict CO_2 user; its CO_2 compensation point of photosynthesis was 5.9—8.2 M. Its net photosynthesis depended on CO_2 according to the Michaelis-Menten kinetics. The K_m was 165±77μM CO_2 and the maximum photosynthesis 99±10 mmol kg^{-1} (FW) h^{-1}. Thus, it is a CO_2 user and high CO_2 concentration in the environment can ensure rapid growth. It was found to be markedly photophilous: its light compensation point was 6.0 W m^{-2} of PAR. Photosynthetic rates rose from 15 to 34°C. The highest photosynthetic rate was found in young apical shoot segments and it declined toward the bases.

[1]From *Aquatic Botany*, 1997, in press, with with kind permission from Elsevier Science NL, Amsterdam, The Netherlands.

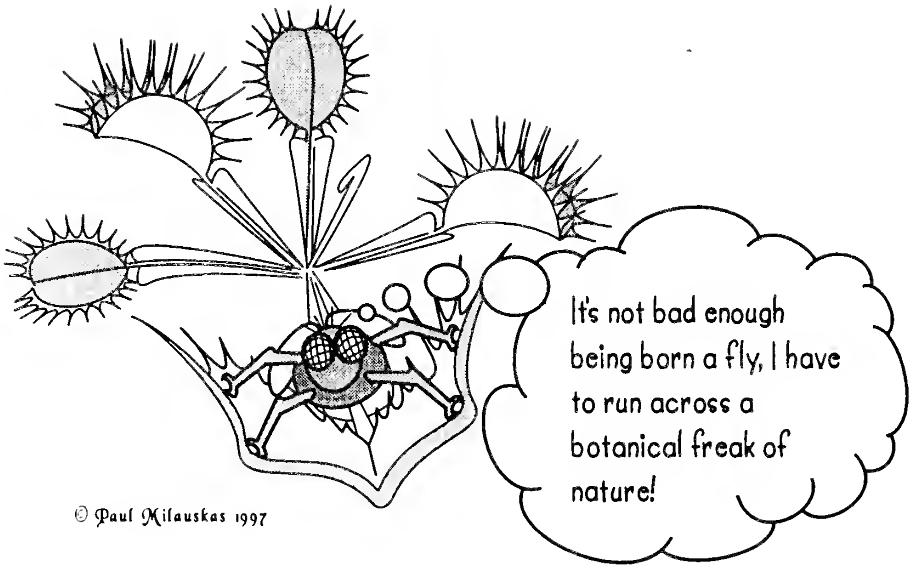
Lake	n	$[O_2]$ (mM)	pH	TA (meq l^{-1})	$[CO_2]$ (mM)	PAR (%)
Miklaszówek	8	0.30 0.24-0.34	7.33 7.19-7.60	4.23	0.44 0.24-0.62	24(3)
Kruglak	4	0.28 0.18-0.39	7.25 7.14-7.46	2.67	0.35 0.22-0.48	36(3)
Orle	1	0.27	7.30	2.42	0.27	n.d.
Krzywe	1	0.26	7.59	2.50	0.14	n.d.
Ostrowo	5	0.29 0.26-0.34	7.10 7.00-7.28	1.60	0.28 0.18-0.36	33(1)
Dlugie	3	0.26 0.23-0.30	5.93 5.80-6.40	1.01	2.55 1.09-3.35	n.d.
Moszne	2	0.09 0.022-0.15	5.69 5.68-5.70	0.57	2.80 2.44-3.16	n.d.
Brzeziczno	1	0.08	5.04	0.16	3.50	n.d.
Mean Median Total Range		0.26 0.27 0.022-0.39	6.15 7.17 5.04-7.60	1.75(12) 1.60 0.2-4.2	0.94 0.39 0.1-3.5	31(7) 28 18-49

Mean values and ranges of values are shown and the number of measurements are shown in brackets. Total mean and range of values are also shown.

n, number of investigated stands.
TA, total alkalinity.
PAR, % of incident light penetrating to the water surface.
$[CO_2]$, CO_2 concentration calculated from pH and total alkalinity.
n.d., not determined.

News & Views

Barry Meyers-Rice (P.O. Box 72741, Davis CA 95617, USA) This spring while exploring *Darlingtonia californica* habitats in California, I discovered an anthocyanin-free form of *Darlingtonia*. Discreet inquiries revealed that Christine Elder, a local naturalist, was familiar with these plants but thought they were merely a flower variant. A complete description of these plants will appear in the next issue of Carnivorous Plant Newsletter, and will include information on how to legally obtain specimens of this new and rare find through the ICPS!



FROM THE PAGES OF CPN 25 YEARS AGO

Joe Mazrimas and another member had comments on *Darlingtonia*. During a trip, Joe "...noted heavy deer depredation, the pitchers standing around decapitated and looking almost like so many *Heliamphora* far out of place. Mr. Isamu states that deer attack the plant to get salt.... The plants are sometimes known as deer-licks."

CPN Growing Pains

Gentle reader,

Starting with the 1998 subscription year, the ICPS dues will increase slightly from $15 ($20 outside the USA), to $20 ($25 outside the USA). This increase will help us to cover recent increases in our postage, allow us to add more pages to each issue of CPN (from twenty-four to thirty-two per issue without exceeding our budget), and make it possible to run more color photos in CPN.

Our backlog of articles has been steadily growing, and we are now nearly a year behind in publishing new material. More pages will help CPN to keep up with the growing interest in CP worldwide and ultimately provide more CP information for you, our members.

In the past, we have avoided generating any surplus funds to avoid tax consequences. Now that we will soon be a non-profit corporation, we can use extra revenue for conservation, education and research projects. Do not hesitate to let us know if you have a project that you think the ICPS should be sponsoring—contact one of the officers at the addresses on the inside front cover and let's talk!

We are also considering multi-year, and life subscriptions, so that we can reduce the renewal crush on our secretary, Ken Cusson. We will keep you posted as things develop.

Thanks for your support,

Rick Walker
ICPS President

Want to help educate YOUR community about CP?

The ICPS is looking for volunteers around the world to help it respond to requests for local CP information, growing tips, etc. from new members, teachers, and interested members of the community.

If you are interested in joining the ICPS Educational Resource Network, please contact:

Jay Lechtman, ICPS Vice President:
11767 Great Owl Circle
Reston, VA 20194-1170 USA

Time and effort will be minimal, but the rewards can be enormous.

(please include your name, address and telephone number(s), and the best time to contact you.)